THE AMERICAN
JOURNAL OF PSYCHOLOGY
Founded by G. STANLEY HALL in 1887
VOL. XXI OCTOBER, 1910 No. 4

VOLUNTARY MOVEMENT

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This paper aims to describe the cognitive aspect of the psychic experience in voluntary movement. It is therefore limited in two respects: first, to the sensory and ideational processes without attempting a detailed account of the feeling processes in such movements; second, it is limited to controlled *movement* and does not attempt an account of what may be called 'inner volition.' More specifically it is limited to the following four lines of discussion.

First. It aims to summarize critically the experimental and more important studies of voluntary movement, particularly such studies as bear upon the problem of the function of the "resident" and "remote" processes.

Second. To describe certain experiments undertaken for the purpose of a fuller description of the cognitive processes involved in voluntary movement and especially for the purpose of describing the gradual automatization of a highly volitional series of acts.

Third. To point out the bearing of certain anatomical, physiological and pathological data upon the rôle of (first) the centripetal impulse and (second) the sensation in voluntary movement.

Fourth. To point out the bearing of all these data upon the general theory of voluntary movement.

I. Literary Orientation

A cursory examination of current psychological text-books and literature reveals fundamental differences of opinion with reference to the universality of the image in mental processes.

Quotations from the following authors will suffice to justify this statement. In his recent text-book (p. 210) Angell writes: "The content of our thought is, so far at least as concerns the knowledge process, always made up of imagery." This position may perhaps be taken as the generally accepted view. Some writers, however, like Dewey hold that "every mental state is as *an existence*, an image." (Psychology, p. 204.) While not expressly stating such a view, Titchener at least implies in his Outlines of Psychology that an image peripherally or centrally aroused conditions every state of consciousness. Opposed to this view there is a small but vigorous group of writers whose position is well represented by Stout, Woodworth and Bühler. Stout argues, in his Analytic Psychology (Vol. I, p. 80), that imagery does not accompany the use of words in ordinary discourse. His reasons are that inasmuch as introspection fails to detect such images there should be "strong positive ground for assuming their presence." In the Bericht über den II Kongress für experimentelle Psychologie (p. 264), Bühler states his position thus: "Welches sind die Bestandstücke der Verschriebenen Denkerlebnisse? Antwort: Vorstellungen aller Art, aller Sinnesgebiete, Sach- und Wortvorstellungen, aber ausser ihnen viel häufiger, reicher und mannigfaltiger andere Gebilde, die am häufigsten als Gedanken, oder in Anlehnung an Marbe und Ach, als Bewusstseinslagen oder Ueberzeugung bezeichnet wurden. Es zeigt sich, dass man Vorstellungen und Gedanken im allgemeinen ganz sicher auseinander zu halten vermag."

After quoting from his own introspections and from those of others under experimental conditions, reporting an absence of imagery, Woodworth goes on to say (*J. Phil., Psy. and Sc. Meth.*, Vol. 3, p. 705) that it is necessary to assume the existence of conscious elements not reducible to sensory terms and that these elements must be looked upon not as "syntheses of sensory qualities, but simply and purely the qualities of particular thoughts."

It will be seen from the above that with reference to the existence of the image in the various mental processes psychologists are divided into at least three camps. (1) A group of writers holding that absolutely every state of consciousness implies the presence of imagery; (2) Another group insisting that at least all *cognitive* processes demand the presence of sensory imagery; (3) A group boldly declaring that even the cognitive processes are or may be carried on without the presence of a sensory or ideational image for every thought item in the process.

What now is the status of opinion when one narrows the field of inquiry to the mental processes that condition voluntary

movement? Here too there are 'camps' though the vagueness in the use of the term 'voluntary,' coupled with its peculiar individual uses and the various interpretations of the current kinæsthetic theory of voluntary movement, make it much more difficult, if not practically impossible, to classify the different positions found in the literature upon the subject. James' exposition (Prin. of Psy. Vol. II, pp. 486-592) of the kinæsthetic theory reveals, as Woodworth has pointed out, the possibility of a wider and a narrower interpretation of this theory. The theory is so familiar that a summary of it seems unnecessary.

The latitude of interpretation which James' statement permits reflects what one actually finds in both earlier and later writers, namely, in some cases, a limiting of the mental antecedents necessary to a voluntary movement to "resident" processes with the possible inclusion of remote visual effects. Ziehen (Intro. to the Study of Phys. Psy., pp. 246-248) and McDougall (Phys. Psy., pp. 163-165) are clearly inclined to this narrower view. On the other hand Münsterberg (Willenshandlung, pp. 88-96) and Angell (Psy., pp. 404-409) give the theory a broader interpretation so as to accord a fuller recognition to James' "very remote" sensible effects.

One of the earliest criticisms, based upon experimentation and observation, of this entire position is found in an article by Kirkpatrick (The Development of Voluntary Movement, *Psy. Rev.*, Vol. 6, 1899, pp. 273-281) in which he reports a study of the motor development of one of his own children. His observations lead him to the conclusion that "there is no evidence that his (the child's) consciousness is concerned at all with the movements he is making in order to get hold of the object and bring it to him,—attention to the movement itself hinders rather than helps in learning the movement." (p. 280.)

Another investigation having an important bearing upon this problem is Bair's study of how we get voluntary control of an entirely unused muscle, the *retrahens aurem* by means of which the ear is moved. (Development of Voluntary Control, *Psy. Rev.*, Vol. 8, 1901, pp. 474-510.) Twelve of the fourteen persons who acted as his subjects had absolutely no control of the ear at the beginning of experimentation. In order to give his subjects the kinæsthetic sensations and images produced by the movement of this muscle, Bair at first caused the muscle to contract by means of electrical stimulation.

His results may be stated both negatively and positively. Negatively he found that the kinæsthetic sensation or image of the movement of this muscle was not in itself sufficient to bring about voluntary control. Positively, he found that before control of a muscle is established the sensation produced by the

reflex or involuntary movement of that muscle must be experienced in association with the sensations from the near-by muscles over which voluntary control has already been gained. He says: "The contraction could not be made voluntarily, not even after it was repeated (artificially of course) a sufficient number of times thoroughly to impress the sensations and definitely to fix the association between the muscle sensation and the visual impression of it." (pp. 499-500.) This appears to imply, that both "resident" and "remote" (visual) sensation were given the reagent without his being able to make the movement voluntarily.

Bair explains that getting control of such a muscle means three things: (1) Producing the movement accidentally through the spread of excessive energy into outlying muscles not yet under voluntary control thus giving a new muscle sensation, or sensation from a muscle from which sensations have not hitherto been experienced. (2) It means the association of this "new" sensation with sensations from muscles already under control. (3) The dissociation of this sensation from the complex of sensations in which it originally arose, so as to be caught separately by attention.

If one distinguishes between sensation and image, a distinction which certainly is not one merely of words, then the findings of Bair's study do not lend unqualified support to the kinæsthetic interpretation of voluntary movement, which explains the whole process in terms of memories or images, "resident" or "remote," of movements which took place involuntarily, or at least non-voluntarily. Bair shows that the memory, or image, of how it feels or looks to have the ear moved is not sufficient to bring about its voluntary movement.

A third experimental study with important bearings upon this question is Woodworth's investigation of "The Cause of a Voluntary Movement." (Studies in Philosophy and Psychology, Garman Memorial Volume, pp. 351-392.) Woodworth's subjects were required to make various movements, some of which, as Angell points out, were probably "too well mastered and too habitual to throw fairly into the foreground the sensory-ideational elements emphasized in gaining control of them." ("Studies in Psy., *Journal of Phil., Psy.*, and *Sci. Methods*, Vol. 3. p. 241.) It is, however, to be noticed that Angell's use of the term "sensory-ideational" implies a failure to distinguish between sensation and image, a distinction of which Woodworth makes use and which has important bearings upon the whole problem.

Out of 128 single introspections Woodworth summarizes the imagery as follows: 27 reported kinæsthetic, 27 reported

visual, 17 reported imagery of other kinds, 30 reported only peripheral sensations, 27 reported an absence from the field of attention of all sensory or ideational imagery. (p. 361.)

Woodworth states that in many of the instances in which imagery was reported, there was what he and Bühler call an "inadequacy" of imagery. This was particularly true of kinæsthetic images which, when present, were found to be unlike the movement that followed. "Sometimes the kinæsthetic represented movement was much briefer than the real movement. Sometimes the kinæsthetic image pictures a slow movement when the resulting movement is rapid. In general this sort of image frequently contrasts with the resulting sensations of actual movement. If we picture how a movement is going to feel and then make the movement we find it feels very different from what we anticipated." (pp. 362-363.)

This illustrates what these authors mean by the "inadequacy" of images. Bühler goes so far as to argue that the "Inadäquatheit zwischen dem Gedankengehalt und dem, was vorgestellt wird" (Kongress für experimentelle Psychologie, Bericht II, 1906, p. 264) is an indirect evidence that thought processes are carried on without imagery. Doubtless he would hold too, with Woodworth, that voluntary action may take place at the instigation of a "naked," imageless, thought.

This concept of the adequacy or inadequacy of mental imagery appears to be borrowed from the physical sciences and transferred bodily to the field of psychology. The argument seems to run thus: If a kinæsthetic image is *the* cause of a voluntary movement, then as such it must contain as much as is contained in the result, just as in physics the cause must, in terms of energy, be equivalent to the effect. Against this position the following arguments may be urged:

(1) The concept of "Adequacy" in the sense that, to be the cause of a movement, the mental image must contain as much as will be contained in the movement, reduces itself, when logically carried out, to a *reductio ad absurdum*. Bühler applies this concept to the thinking process, as has been shown, and concludes that images are not necessary to complex thinking processes because the image is frequently "inadequate." But why stop with movement and thinking? Why should not the same argument be applied to all mental processes and finding that everywhere images are "inadequate," as they certainly are, in the sense in which these authors seem to use the term, conclude that images are not essential to any of our mental processes, and thus rule the image out entirely and regard it as a really useless thing in all forms of experience?

(2) It is not always true that "the adequacy or inadequacy of images is a point of importance in judging how much of a real causal function the image has in the production of movement." (p. 362.) Many things come in to modify this "importance" of the adequacy or inadequacy. Reflexes, instincts, habits and "psycho-motor" tendencies all come in to supplement any lack that may exist on the part of the initial image. And, what is still more to the point, the immediately inflowing sensations, once a movement is started, are of incalculable service in the further control of it. Woodworth himself has pointed out that the coördinations of a movement are unconscious processes. The details, therefore, of a movement need not be included in the image in order that it be adequate.

(3) This idea is not a psychological concept. It is rather a logical, *a priori* idea, and as such practically the same argument may be urged against it that Woodworth presents in opposition to the image theory, namely, that it is too "schematic." As a sort of logical necessity it is apparently *assumed* that *to be adequate* the image *must* contain what will be contained in the forthcoming movement, and *then*, when introspection reveals that the image does not contain qualitatively and quantitatively what the movement sensations reveal, it is *therefore* declared "inadequate."

Woodworth refers also to his own attempt to learn to move the great toe in isolation from the others. "The establishment of complete voluntary control is a very gradual process." (p. 36.) He finds, too, with Bair, that the first success comes by accident. Gain in control is then made by directing attention to the member itself. In this, too, he agrees essentially with Bair who found that the final stage in getting control of a muscle consists, as has been stated, in dissociating the sensation of the movement of the muscles in question from the sensations derived from other and already controlled muscles. But while the kinæsthetic *image*, and in fact imagery of every sort, is entirely unnecessary, Woodworth holds, that kinæsthetic *sensations* from a member are indispensable, maintaining that "sensations are indeed always present, as contributing factors in determining the act. They represent the existing situation with reference to which the act is performed, and the act is determined by the existing situation as well as by the intention." (p. 383.) This position will be referred to again in the discussion of the relation of sensation to movement.

Thorndike calls attention to five facts, which in his judgment argue against the kinæsthetic theory.

(1) The same imagery will frequently be found employed

in willing *not* to do a thing that we find in willing to do it. This fact he regards as a good reason for the suspicion that in willing to do a thing the image of doing it comes as a natural consequence of the idea and *not* "as a necessary dynamic factor in the action."

(2) "We can will acts images of whose resident sensations are not obtainable." This position, he holds, is supported by the fact that we can perform many operations in less time than it takes to call up the imagery. For example, one can write a combined series of figures, letters, dots and dashes in less time than it takes to call up the various resident or remote images representing the various movements. To this, doubtless, the supporters of the image theory would reply that all such movements have been practiced until so completely habitual as no longer to require the presence of the imagery that functioned at the time the movements were learned.

(3) In many of our voluntary acts we will to do things so complex that it would take all of us several minutes to call up the imagery of the series of movements involved. For example, we can will to draw a polyhedron of 28,000 sides.

This objection is apparently based upon the erroneous idea that such a complex act as the example given is a single act. To draw a polyhedron of 28,000 sides is clearly not a single act but a connected series of acts, from both psychological and physiological points of view; and therefore, if it calls for imagery at all, practical necessity would demand a series of images and not a highly complex image before beginning the drawing.

(4) "In trying to get any one to make a voluntary movement we rarely take means specially useful in calling up the images of resident or remote sensations, and often do take means specially to prevent their appearance."

(5) "If we insist on the image's effective presence we make voluntary action sharply discontinuous with involuntary action." (The Mental Antecedents of Voluntary Movements, *Jour. of Phil., Psy., and Sci. Methods*, Vol. 4, 1907. pp. 40-42.)

The experimental study by Ach, Ueber die Willenstätigkeit und das Denken (Göttigen, 1905,) is perhaps the most systematic investigation of this question thus far made. Ach's position, it will be observed, agrees in a measure with the position of Woodworth and Thorndike.

Previous studies of voluntary movement, Ach finds, have for the most part been confined to reaction-times and have, therefore, neglected the psychological processes involved. The analysis of these processes is the author's object. He used simple and complex reactions with the Hipp chronoscope as the recording instrument.

With relation to the content of consciousness present in the various reactions employed Ach expressly states or implies the following observations:

(1) The particular content of consciousness present in a given reaction varies, first with the individual tendencies. ("Individuelle Veranlagung spielt hier eine grosse Rolle.") It varies also with practice and, thirdly, with the apperception of the stimulus.

(2) The mental processes involved in all voluntary action are in no small degree determined by what the author calls "determining tendencies." These tendencies are the results of the presence of an idea of a *goal* or *end* to be accomplished by the reaction. In themselves these tendencies may be entirely unconscious, but they are nevertheless essentially effective in shaping the mental content controlling the reaction.

(3) When the reaction itself takes place there is no discoverable "will" process or content, as such, present. All this comes at an earlier period when the subject consents, as it were, to the procedure as a whole.

(4) Ach and his subjects discover in the content of the volitional consciousness what may be classed as two sorts of sensation, both, however, being *necessarily* present *only* in the early and unlearned stages of the reaction. Both may be entirely absent at the later and familiar stages. The first sort of these sense processes is made up of the usual peripheral sensations set up by the stimulus. The other class, highly important in Ach's account, is essentially kinæsthetic sensations. Ach prefers to call them "intentionalen Bewegungsempfindungen." They are, however, he tells us, "Spannungsempfindungen" and have their origin in the muscles. Their function is to give us the trend or direction ("Richtung") of the forthcoming movement. Ach speaks also of sensations which are mere accompaniments—Begleiterscheinungen—which do not appear to serve any particular function.

(4) Then there are all sorts of memory images, visual, acoustic, kinæsthetic, etc., which present themselves most frequently in the early stages of voluntary action and then disappear more or less. Upon the presence of these images, which constitute the essential elements in the image theory, Ach does not appear to lay much stress.

(5) Finally there is present, particularly after practice and frequently in the period after the ready signal has been given (Vorperiode), a functional mental content—and sometimes it constitutes the entire consciousness of the moment—in which no *imagery at all* is to be found. This consciousness is at times entirely without sensations of any kind; even the highly important "intentionalen Bewegungsempfindungen" are wanting.

"Wir bezeichnen dieses Gegenwartigsein eines unanschaulich gegebenen Wissens als Bewusstheit." (p. 210.) This "Bewusstheit" which is characterized by the "Wissen" that it contains cannot be further analyzed. However, in his discussion of this imageless and sensationless state of consciousness Ach brings out the following facts concerning it: (a) Its constituent parts (*Bestandteile*) fade with repetition. (b) The intensity of the *Bewusstheit* decreases with practice and familiarity. (c) The whole process may be designated as a lessening of concentration of attention.

(6) The further fact is to be noticed that the *Bewusstheit* is *always* immediately preceded or accompanied by sensations (Spannungsempfindungen), visual, acoustic, kinæsthetic, etc., or by a memory image of such sensations. The clear, unequivocal content of the imageless consciousness does not, however, in Ach's judgment warrant describing it in terms of indistinct sensation or memory representations.

(7) It would appear then that this imageless content is not a *derived* consciousness but is, as Woodworth puts it, an original consciousness having a distinct quality of its own.

Another study throwing light upon the problem of the necessary elements functional in voluntary movement is that by Downey. (Controlled Processes in modified Handwriting. *Psy. Rev. Monographs*, Vol. 9, No. 1, pp. 1-148.) Downey studied handwriting under modified conditions, such as elimination of visual control by blind-folding, mirror writing, inverted writing, embarrassment of motor control with and without vision, etc.,—and also under conditions of distraction. The more important results bearing upon this study may be summarized as follows:

(1) Throughout the tests the reagents fell into two groups, one emphasizing visual, the other "grapho-motor" control.

(2) "Individual variation was the extent to which the subject had recourse to grapho-motor control either conscious or automatic." (pp. 51-52.) But "when the break up in the motor coördination was sufficient to demand the acquiring of a new writing reaction the former reagents (grapho-motor group) tended to use consciously more motor material than did the latter (visual group). The form of the break-up usually occasioned intensification of the visual control." (p. 140.)

(3) In the distraction tests the grapho-motor group "showed the strongest tendency to write more or less automatically; the second group the strongest tendency to control writing consciously." (pp. 125-126.)

(4) "Mirror writing increased the tendency to rely on grapho-motor control, a surrender partly to motor automatism but partly also a control by motor anticipation," but "in in-

verted writing . . . there was a gain of visual over motor control." (p. 52.) In the case of one reagent "the visual material represented a pseudo-control, but with the embarrassment of the motor situation it became actually directive." (p. 46.)

(5) A negative result of much importance for a later section of this paper is to the effect that "no evidence was found for the initiation of a *voluntary* act [italics Downey's] of writing without a sensory cue of some sort." (p. 142.)

(6) Another important result is that "throughout the whole series of experiments the *report* coming from the writing in terms either of kinæsthetic or visual sensations and images, proved to have a highly important function as part of the writing cue." (p. 142.) "A sensory kinæsthetic report on the movement as it proceeds is of course usually present, although it varies apparently in vividness and accuracy from individual to individual and has a different value for the same individual under different conditions." (p. 7.) "Many lapses occurred in B's writing of the verse, due, he asserts, to the lapsing or retarding of the grapho-motor report." (p. 63.) "Open errors frequently resulted from the lapsing of the grapho-motor report from the writing and were most often found in reagents of the first (motor) group." (p. 142.)

(7) "When automatic writing occurred, it was apparently, purely physiological in character." (p. 142.)

(8) In contrast to Ach and Woodworth's findings, Downey brings forth no evidence whatever in favor of an imageless consciousness which is at the same time operative in effecting control.

(9) Although "the experiments offer some evidence (which, however, is not 'unambiguous') for the existence of grapho-motor imagery"[1] (p. 142), it is, however, perfectly clear that so far as control is concerned there is no evidence showing that such imagery is necessary.

To turn now to the broader aspect of this subject, it would appear that there are three important psychological concepts that have an indirect bearing upon the problem of voluntary movement. They are: (1) The Reflex arc concept. (2) The concept that *all* consciousness is motor. (3) The concept of motor and sensory forms of reaction.

Dewey has shown (The Reflex Arc in Psychology, *Psy. Rev.*, Vol. 2, 1896, pp. 357-370) that the reflex arc concept should be given a fuller recognition in the study of movement and also in the study of all conscious processes and that once given such a recognition this concept necessitates a readjustment of psy-

[1] *Cf.* Book: The Psy. of Skill, p. 54. Montana University Studies, Vol. I, No. 1.

chological procedure. Our present terminology and analyses, he points out involve an unfortunate dualism, like the dualism of body and soul to which it harks back. We have been accustomed to think of the sensory stimulus as one thing, the central activity, standing for the idea, as another, and the motor discharge, standing for the act proper, as a third. But instead of viewing these elements as each a distinct entity, they should be viewed as "divisions of labor, functioning factors, within the single concrete whole, now designated the reflex arc." (p. 358.) A stimulus always breaks into a coördination and not into a sensation mass. Whenever we turn round upon ourselves what we find is a coördination, an act taking place. Within this act lie both sensation and movement as phases of it.

On the basis of this conception this much may be laid down, namely, that voluntary movement never starts *de novo* and never begins with a mere sensation mass; it always breaks in upon an existing coördination. But when consciousness plays a part in the formation of a new adjustment or rather the modification of an existing one, attention is directed to the sensation phase of the coördination because this phase represents the existing situation with reference to which the adjustment is made. When, now, one asks, precisely what elements of the sensation phase of coördination must attention be directed to, any of it, all of it, or only *certain* elements of it, the position of the image theory at once becomes arbitrary; for, to be consistent, it must hold that *immediate sensations are not* a sufficient basis upon which to make a volitional movement,—there must be present *images* of sensations experienced in involuntary and reflex activity. The objections here raised are that this position is first of all highly arbitrary, and secondly, as Thorndike has pointed out, puts volitional over against involuntary activity so as to make the former radically distinct from the latter. Moreover, whether we regard voluntary movement as an activity developed out of original reflexes, or whether we regard reflexes as the products of conscious impulses and volitional control the relation between them, in either case, is rendered arbitrary if we take the position that in voluntary action *certain* senses and ideational elements are the essentials while in other forms of activity any peripheral or central processes that bear a relation to the situation with reference to which the act is performed are sufficient.

At this point the theoretical exposition of "Consciousness and Movement," by Judd, based upon a variety of experimental studies by himself and his associates in the Yale Laboratory, is significant. Judd calls attention to the distribution of the sensory areas in the cortex. "The sensory centres," he says, "except the centre for touch, are distributed in the

highest brains in such a way as to be relatively isolated from each other and from the motor area. The association areas which link these widely separated sensory centres are clustered in unmistakable fashion around the motor area." (*Psy. Rev. Mon. Supp.* 7, 1905, "Movement and Consciousness," p. 207.) Judd holds that all paths lead to the motor area through the associational tracts; that the higher senses do not "reach the motor areas *through* tactual centres." (p. 209.) He points out that muscular and tactual sensations are unrefined and that "requirement of sensory control and refinement of movement go hand in hand. Why, then, should the conscious processes in which visual factors are fused be continually referred back to a primitive form of sensation for their explanation?" (p. 218.)

The bearing of Judd's contention upon the problem of this paper is evident. All impulses move toward the motor area; sensations do not arouse other sensations but motor responses. The higher and phyletically later sense processes are more "refined" than the older tactile sensations. The later acquisitions, therefore, more accurately represent the situations to which adjustments are made. There is, therefore, no reason why images of these later and more refined sense acquisitions should not, so far as any imagery at all may be concerned, play as original and important a rôle in volitional acts as any other imagery.

In the language of James, "All consciousness is motor," a fact so frequently demonstrated as to be a commonplace. But if the image theory of voluntary action is strictly interpreted some elements of consciousness under volitional conditions require the presence of additional conscious data in order to become effectually motor. To put it in the physiological terms in which Judd has expressed the situation, some sensory impulses cannot pass over into motor impulses without first arousing certain other sensory activities which are the physiological correlates of previous sensory experiences obtained under involuntary conditions. In fine, if the image theory is interpreted in accordance with the scientific usage of psychological terms it involves a serious modification of the proposition that 'all consciousness is motor' in case of all reactions above the level of the involuntary and the habitual. Here once more we are face to face with a break between the voluntary and involuntary which in turn involves a gap in the image theory not yet bridged over by its supporters.

There is a third concept current in the psychology of movement which is apparently difficult to explain on the basis of the image theory. This is the notion of sensory and motor forms of reaction. When the subject is making reactions that

are highly volitional, as has been frequently the case in studies of reaction time, how is it possible to have a sensory type of reaction at all? Suppose, for example, the subject is reacting with his toe or his lips as in the case of Angell and Moore's study. In this case the image theory would demand that before the subject could make his reaction there must appear in consciousness some kind of image of the movement itself. Here, then, it would be misleading to speak of a sensory type of reaction for the reason that the image of the stimulus would have to be followed by an image of the movement either as felt, seen, or experienced in some other form, before the movement could be made. That the intervention of such an image does not necessarily take place, particularly after practice, is pretty well established by Ach and (by implication) by Downey and by experiments to be described later in this paper. This makes the concept of sensory and motor types of reaction correspond to what the names imply and to what has been commonly understood to be the distinction between them.

In interpreting his own theory James has said: "In the chapter on the Will we shall learn that movements themselves are results of images coming before the mind, images sometimes of feelings in the moving part, sometimes of the movements' effects on the eye and ear and sometimes (if the movement be originally reflex or instinctive) of its natural stimulus or exciting cause." (Vol. I, p. 445.) The literature reviewed and the arguments already set forth demand a modification of this position.

It is clear that much of the older literature bearing upon voluntary movement is not only general in character but to a degree at least *a priori* in its derivation, and hence, as Woodworth has pointed out, logical and schematic rather than strictly psychological in its treatment. The weakness of these older studies is therefore primarily methodological but a weakness which in turn brought errors of result and interpretation. Another methodological error that has crept into certain more recent studies of voluntary movement is that of studying thoroughly practiced movements, and from such study drawing inferences with reference to voluntary movement in general. 'To instruct a person verbally to make certain very familiar movements and then from the absence of supplementary imagery to draw the inference that imagery in general is not necessary for voluntary movement' (*cf.* Angell's review of "The Cause of a Voluntary Movement." *Jour. of Phil. Psy. and Sci. Meth.*, Vol. 3, pp. 641 f.), is not only an error of fact, as will be shown later in this discussion, but is primarily an error of procedure which leads directly to the error of fact.

To avoid such errors the study, to be described, is based primarily upon new and unpracticed movements and also upon highly voluntary movements practiced until they became nearly automatic.

II. Description of Experiments

The movements studied were the following:

(1) Writing ten standard words on an apparatus resembling a typewriter until the reactions became practically automatic.

(2) Writing with the hand under novel conditions and also with distraction.

(1) Typewriting experiments.

The problem in these experiments was to describe not only in cross-section the cognitive elements involved in control but also to trace the gradual elimination of these conscious elements up to the point of automatism.[1]

The apparatus used was constructed by fastening ten small rubber bulbs upon a board about sixteen inches long in such a way as to fit comfortably the fingers and thumb of each hand when placed upon the "keyboard." All the bulbs were connected by means of a rubber tube to a single tambour writing upon the drum of a Ludwig kymograph, which was placed on the opposite side of a screen from the subject. The bulbs were "lettered" by means of letters printed upon a cardboard strip and corresponded to the lower row of keys of the Blickensderfer typewriter. From these letters the following list of ten four-letter words was made up: *tons*, *hear*, *tide*, *road*, *hits*, *shin*, *nods*, *dear*, *heat*, *iron*. It will be observed that out of a total of 40 letters each letter occurs four times, thus giving all the fingers equal practice. A graphic record of the writing of these ten words was taken on a kymograph drum at the beginning of each sitting, the writing being to dictation of the words by the conductor of the experiment. This was followed by a brief "practice" period, at the conclusion of which a second record was taken in the same manner. At first the "practice" consisted of ten repetitions of the standard words with the list placed where it could be conveniently seen; but after the list had been memorized the words were written also five times with eyes closed in addition to the ten times with eyes open.

The difference between these movements and those of gen-

[1] The experiments of this section were undertaken before the publication of Book's study above mentioned, and with only indefinite knowledge of his general results. Since then his paper has been read with care and in many ways found to support the main theses of this paper. A review of it has seemed impractical, however, on account of limited space.

eral typewriting consists in the fact that after the subject had once learned the order of the letters on the keyboard and the list of words to be written he knew at each point in the series of movements just what was to be done next. Indeed, in their general nature these movements resemble complex reaction-time experiments involving discrimination and choice, rather than ordinary typewriting, differing from the former only in the fact that the stimuli were given in a uniform order.

The four subjects *C*, *D*, *E* and *R* who served for this experiment were graduate students in the department of psychology of Clark University. Each had had experience as a reagent prior to this experiment. *C*, *D* and *E* gave thirty sittings, each writing the list on the average nearly 500 times. Besides the brief "practice" period mentioned, *R* also wrote the list from ten to twenty times per day for additional practice, thus writing the entire list a total of over a thousand times during a period of seven weeks.

That these movements became practically automatic with daily practice in a few weeks' time is not surprising when the simplicity of each movement taken by itself physiologically is considered. The simplicity of the movement as compared with ordinary writing or throwing a ball, is in itself sufficient to account for the rapidity of automatization. This fact was a decided advantage since it permitted a genetic study as well as a cross-section study which was all the experiments on ordinary writing afforded.

The most striking characteristic of the first stage of control in these type writing movements is the pronounced dependence upon the eye on the part of every subject. This was true not only when writing from the list in "practice" but also when writing to dictation for the records. In this first stage while writing to dictation the subject apperceived the word by pronouncing it in inner speech, then repeated, in inner speech, each letter while running his eyes over the "keyboard" to locate each letter of the word before the writing (*i. e.*, pressing the bulb) was begun. In addition to fixating each letter before the word was begun, it was again attentively fixated when the corresponding bulb was pressed, making a double visual sweep of the cardboard guide which carried the letters. Not only was this true, but in case of the two subjects *C* and *R* who had had no especial practice in controlling the fingers separately, such as is afforded by typewriting or piano-playing, *the attentive fixation was extended from the letters on the cardboard to the corresponding bulbs as each was pressed.* The other two subjects, *E* and *D*, one a practiced piano-player, the other a typewriter, gave no indication of fixating the bulbs during this first period.

This difference, we are inclined to believe is not accidental, but directly due to skill previously gained in the separate control of the fingers, the skill thus acquired showing itself in the ability to write as readily without bringing the point of regard so close to the fingers as was done by the other two subjects. *C* and *R* focussed *every separate objective* item involved in the writing with the exception of the fingers.

While inner speech was distinctly conscious at this stage, there are no reports showing that it became a focal element. It would seem that the inner speech in this case was very much the same as it is in silent reading; attention is upon the page and the meaning and never upon the inner speech as such. Inner speech reacts upon and modifies what is attentively seen (or heard) instead of what is seen (or heard) reacting upon and modifying what is present in inner speech.[1] Indeed the latter would involve a complete reversal of the situation as it is given to the subject, for the reason that what he starts with is, in practice, a fixated word, and in dictation a heard word. Meaning always implies the associative play of another process upon the one that *has* the meaning. It is clear that a sense process cannot possess *conscious* meaning in and of itself; it must call up something, be reacted upon by something, to have meaning. In this case the visual sensations flowing in from the list of words or the auditory sensations flowing in by virtue of the dictation, are reacted upon by inner speech and thus get their meaning. In this sense the "inwardly spelled word" is the immediate cue for the consequent movements, *although the entire cue is always the total situation as perceptually cognized by focal and marginal processes.* Inner speech was at first more or less strongly muscular on account of the effortful nature of the whole performance. Another characteristic of this first stage of the movements under discussion is that the muscular sensations, though clearly conscious, are never focal, except when by virtue of their intensity they may *distract* attention from the copy. For example, at his first sitting subject *C* complains of "a feeling of jerkiness" and that the "muscular currents are interrupted" and significantly adds, that the process is "not pleasant." This subject was the first to break away from the visual use of the "key-board" which he did at his fourth sitting, having learned in their order the letters on the key-board. Here then was an opportunity for attention to muscular sensations to show itself if occurring at all during this period of learning. But the report for this sitting contains the statement that the subject is "conscious of the bulb to be pressed rather than of the finger to do the pressing." It is

[1] *Cf.* Book: *op. cit.*, p. 157.

only when the situation is new and highly stimulating and the consequent "overflow" considerable that the muscular sensations claim direct attention, and perhaps only then when the subject is on the lookout for them. Here again we have an instance tending to show that when learning to make movements that involve objects other than the body attention is upon the sensations arising outside the body and not upon those arising within the body.

With minor exceptions there is no evidence that during this learning period our subjects made use of either resident or remote imagery of the forthcoming movement. There is not an introspection indicating that any one thought of how the movement, about to be made, was going to "feel" or look. The only functional imagery, distinguishable from the sense and perceptual processes involved, was inner speech, and even this was at this time more or less muscular. One of the "minor exceptions" just referred to, was the idea of the result of the movement, which figured only in the dictation writing. This idea was the idea or visual image of the result of the movement of the writing point upon the drum surface. It is therefore clear that during this first and most difficult stage of control, attention is objective and perceptual.

The second stage leading towards automatization is characterized by a "short circuiting" process in which certain perceptual elements drop out, and, if consciously present thereafter, are represented by memory images. The first elimination is to be found in the disappearance of excessive eye movements over the key-board when a general idea of where to look for the letters has been reached. At this stage the different methods presented by different subjects began to manifest themselves. As previously stated, *C* consciously freed himself from the key-board very early by learning the letters for each bulb and then using the "touch method." Even on the second day "the effort is to make automatic the coördination between *memory* impressions of the letter on the cardboard and the motor impulse." On the fourth day he is "trying to avoid looking at the cardboard entirely," but he has not yet "got the letter translated into the bulb," *i. e.*, he has not "short circuited" so completely as to "take directly from list to bulb." *C*'s short-circuiting method was therefore that of eliminating eye movements over the letters on the cardboard and substituting for them the visual memory image of each letter and its location until a direct association between letter and bulb was set up. *E*, trained upon the piano, followed essentially the same method. For example, at the fourth sitting *E* "can make the movement of pressing the bulbs in shorter time than it takes to place (*i. e.*, to fixate)

the letters on the cardboard," and is already visualizing the letters infrequently and remembers their places in terms of motor activity. Here we have first the elimination of direct vision of the letters and a little later the elimination of the visual memory images of the letters, at least to a degree.

R fell into the other method, that of learning the list of words early in the practice and thus freeing the eyes for constant use upon the key-board. This eliminated eye movement from list to key-board and *vice versa*. On the second day *R* speaks of a greater ease in execution in consequence of having now "a general idea of where to look for the letters." After a few sittings *R* still further eliminated direct eye-movements from letter to bulb, so that the pressing of the bulb followed immediately upon the fixation of the letter. *R* also reduced eye-movements by gradually ceasing to fixate each letter as the corresponding bulb was pressed, and instead fixated the central part of the cardboard with only slight fluctuations on either side.

D never made direct eye-movements from the letter on the cardboard to the corresponding bulb. His method was essentially the same as that of *R*, with the exception that he used the list of words for a longer time. He did, however, early begin to eliminate eye-movements over the cardboard and the fixation of each letter. At the second sitting he thinks there is some motor memory present and finds that when the movement is once started the "visual element becomes peripheral and almost drops out." At his eighth sitting he "fixates only the central part of the cardboard and makes use of the outlying letters in peripheral vision." A day or two later he reports that he "did not have to look at the letters on the cardboard." This was on the day when eye-closed "practice" was begun. He was, however, still looking at the list of words, which practice continued for a considerable time after the words had been committed to memory.

These details have been given to illustrate what is meant by what has been called the "short circuiting" process. They illustrate the general principle of initial excess of activity which characterizes all learning processes, a principle to which voluntary movement offers no exception; for voluntary movement is genetically a learning process, though it differs from certain learning processes in this respect, that much of what is eliminated is not necessarily faulty but at the beginning useful and even necessary. It is therefore not so much an elimination incident to "trial and error" as an elimination due to what may be called a knitting up of the associative links between the various sensory and perceptual processes involved in the control.

Another fact to be observed here is that, as this "short-circuiting" process takes place, control as a whole shifts from what at first was almost, if not wholly, peripheral, involving a hunting about with effort, to what may be called a central control, securing precision and ease in the sense that the operator knows just what to look for and what to do, and in the further sense that the association links between the factors involved in control function without mental effort. In figurative language the subject has at his command a panoramic map of the whole mental situation and the transition from one focal point to the next on this map tends to become automatic. As the "short-circuiting" and knitting-up process takes place, the tendency is clearly present to pass from what was first a disjointed mass of details to what becomes a complex unity. Gradually organization comes out of chaos; and, with organization, details as such lose their distinctness and merge into a situation which in course of time requires attention not to separate details or series of sensations and images, but only to a *total situation.* But the situation does not become an attended-to situation until the "short-circuiting" process has reached a certain degree of completeness. Reduction of sensory and perceptual data to a minimum is therefore necessary to bring about a movement-situation in which the details run off without attention to them as such.

The possibility of consciously organizing a given group of movements into a control situation requiring only a single "set" of attention is therefore determined by the nature of the movements on the one hand and the span of attention on the other. Just as some of our movements surpass the physiological limit of becoming reflex—at least in a single life-time—just so other of our movements surpass the conscious limit of becoming controlled by a single "set" of attention. This "set" of attention, *i. e.*, attention to the organized situation, is the third and last stage reached in the movements under discussion. A fuller description of this "set" as it appeared in the experience of the four subjects participating in this experiment is now in order.

It is scarcely necessary to call attention to the fact that this so-called "set" of consciousness is not a purely mental state but clearly a psycho-physical condition involving the whole musculature as well as the neural and conscious aspects of the organism. It is a movement-consciousness with habituated motor tendencies. But while the motor processes accompanying and flowing from the "set" become habitual and ultimately highly automatic, and while the distinguishable *contents* of the "set" are also highly involuntary, *the maintenance of the "set" itself is the remaining voluntary aspect of the whole process.* The introspections of both *E* and *R*, with whom the "set" was most

highly developed, abundantly illustrate this fact. For example when *E*'s attention, during the last days of experimentation, wandered too far away from the process the writing stopped. The inability to continue the writing was not, however, due to "any less attention to the details" but to "lack of attention to the general situation." *R* reports that all that is required to keep up the proper movements is a certain general "direction of attention" or "general attitude," and that if this is maintained the details take care of themselves.

But if the details as such receive no attention how is it that mistakes are recognized immediately after they occur, a fact which was often noticed? If a wrong movement is recognized, it must rise to the level of consciousness as a distinct movement, and this is precisely what happens. When the movements run off correctly and smoothly we have a condition which Hobhouse well describes when he says that the "crude sensation has assimilated certain characteristics which, if disentangled, form the contents of ideas, but which are not disentangled as long as they are assimilated. Prominent among these are motor-impulses. We may call them acquired sense impulses, and say that the present stage of assimilated experience postulates sensations and feelings as its data and produces acquired sense impulses passing into habit as its result." (Mind in Evolution, p. 101.) But the sensations from wrong movements have not acquired the idea 'characters' and the 'motor impulses' that characterize the sensations from correct movements and hence at once rise to the level of distinct consciousness. They are instantly disentangled from the other contents of the "set," for they never really belonged to the "set," and being alien to it, at once attract attention when they appear. It is therefore clear that the muscular sensation or after-image of the correct movement is quite a different thing from the muscular sensation or after-image of the wrong movement. The former is reacted to as a sensation in peripheral consciousness, if conscious at all, the latter gives rise to a focal idea which calls for a special reaction. The former appears as an unnoticed element in a consciousness acting as an accompaniment or mere spectator, while the latter immediately gives rise to a consciousness acting as a "guide"[1] for each detail.

Attention to details invariably made the writing more difficult after the "set" was established. The general principle seems therefore to hold, so far as voluntary movement is concerned, that consciousness exists only to get rid of itself, and that when once rid of itself the adjusted movement runs

[1] *Cf.* Morgan: Intro. to Com. Psy., p. 189.

off best when as nearly unconscious as the conditions will permit.

This position is further supported by the fact that in no case did the "set" appear until the writing of the list of ten four-letter words had become a series of forty consecutive associated finger movements; that is, until the words, and to a degree the letters, as such had dropped out or, perhaps better, become merged with the movements and the sensations resulting from the movements, so as to be concretely indistinguishable. For example *E* reported at the close of experimentation that "general bodily sensations and tactual-kinæsthetic sensations, together with visual sensations when the eyes are open, make up the content" of the "set." This and other introspections illustrate that the gradual drift of attention is from the extra-bodily factors, with which attention is concerned at the beginning of the experimentation, toward the intra-bodily sensations as the activity becomes automatic until finally attention to details as such is lost. It is then that the tactual and kinæsthetic elements and the inner speech are observed as the only remaining sensory or ideational elements connected with the activity; and these no longer demand a shift of attention from one to the other but all enter into an organized complex with attention given to it as a whole, and without distinction of inner or outer.

This description holds only for the "practice" writing and not for writing from dictation. At the beginning of experimentation one or two of the subjects thought writing from dictation easier than from the copy, but at the close all agreed that the dictation was much less automatic than the "practice" writing. The reason for this is found in the fact that after the "set" had developed to a certain degree the dictation (a word at a time) periodically interrupted a process which had become continuous and automatic.

The dictation writing at this stage illustrates two of Ach's observations, namely, the presence of intentionalen Bewegungsempfindungen and the absence of imagery between the reception of the word and the following movement. (*op. cit.* p. 146.) In dictation the subject develops, so to speak, a special or temporary "set" for each word by running through the word in inner speech with reference to the letters on the cardboard or the corresponding bulbs or fingers, depending upon the degree of automaticity already attained. In early practice this process was repeated essentially *after* hearing the word and *before* beginning to write, but after the appearance of the "set" there was no discoverable imagery intervening between the apperception of the word and the beginning of writing. What is found is simply a psychophysical "set" for the par-

ticular word anticipated, and with the reception of the word the release of the motor consequences (temporarily inhibited) of this "set," which already contains the movement in embryo.

Inner speech continued throughout experimentation, but in the fully developed "set" it cannot be regarded as the motor cue. That it cannot by itself be regarded as the cue is shown by the fact that not infrequently the movements outstrip the inner speech for the corresponding letters. *That neither inner speech nor any other single factor can be regarded as in itself the cue is further demonstrated by frequent instances in which the movements were ahead of any sort of consciousness of the process.* In fact, with both *E* and *R* in the last days of practice the moter impulse was at times clearly ahead of all detailed conscious processes. When consciousness of the movement came into the process at such times it always came in just a little behind what the fingers were doing. But this is not to be interpreted to mean that consciousness had nothing to do with the movements and that the latter had become purely physiological. Far from it. There was a distinct limit to both the separation in time and the nature of the possible withdrawal of consciousness from the movement. If in rapid writing the movements succeeded each other so rapidly that the consequent sensations merged into a sensation-mass and inner speech became indistinguishable or some of the letters were slurred or omitted, the "set was broken and control was momentarily lost. Again all the subjects found it possible at the close of experimentation to think of other things while writing, without interference. But here, too, there was a limit. It appears that, as one subject observed, considerable quasi-irrelevant imagery may enter consciousness without serious disturbance, provided it is all related to the writing. This irrelevant, but non-disturbing, imagery is only momentary "like a flash" or "like a dream." Otherwise the writing "set" is disturbed, if not actually broken up.

This brings us to another point in the discussion, namely the difference between the "set" with eyes open and with eyes closed. There are two differences, a difference in the rate of the writing and a difference is distractability. Some of the subjects were inclined to think, on purely introspective grounds, that they wrote as rapidly with eyes closed as with eyes open. The facts (as revealed by the special records of the "practice" writing taken for this purpose without the subjects' knowledge) are, however, that *in every case* the eye-closed practice was slower than the eye-open; and this in spite of the fact that only two of the subjects visually regarded the card-board containing the letters. This is shown in the following table of averages

for writing the list of ten words or forty letters. *R*'s averages are based upon 50 records; *E*, *C* and *D*'s upon 30 records each. The numbers express fifths of a second.

	Eyes open	Eyes closed
E.	28.2	29.7
R.	35.6	39.7
C.	47.8	54.7
D.	52.5	70.2

D and *C* show the greatest differences. *D* practiced with eyes upon the cardboard in open-eye practice while *C* did not. Whatever the reason for these differences, it is clear that open eyes facilitated the writing even when the cardboard and bulbs were not regarded. It is possible that these time differences are due to differences in liability to distraction. This latter difference shows itself in the difficulty with which eye-closed practice records were obtained. Not only were mistakes more liable, but there were actual "break downs" when the attempt was made to obtain the eye-closed records, due to more pronounced consciousness of the rotating drum, etc. Such broken records were of course not used in obtaining the above averages. It is possible that the eye has a steadying effect upon voluntary movement, because of the original close connection this sense organ sustains with all our voluntary activities involving objects or extra-bodily space. It is possible, too, that vision aids by holding the external circumstances of the experiment in consciousness, at least in a peripheral way, and thus by association helps to maintain the "set." At any rate the "set" of consciousness here described was more readily maintained in eye-open than in eye-closed practice.

To summarize, The automatization of a highly voluntary movement like the one here studied, involves the three following stages:

1st. A period of perceptual attention to details in which vision plays the leading rôle, the muscular sensations being only marginal, unless abnormal conditions, subjective or objective, force them into the focus of consciousness.

2nd. A transitional period, or period of adaptation, which is characterized by three things: (a) A process of elimination of perceptual data and, in instances if not in all cases, the substitution of memory imagery, for a longer or shorter period, for the eliminated perceptual data. (b) A gradual lessening of the intensity of attention and of general psychophysical tension. (c) The development of an organized "set" of consciousness in which the details no longer require attention in themselves but only as parts of a complex whole, the elements

of which are sensuous, rather than perceptual, but have yet the *motor* significance of perceptual or sense data attended to.

3rd. A period in which the volitional part of the process consists only in the maintenance of the "set," the details which enter into it taking care of themselves, provided the "set" is not disturbed beyond a certain degree of habitual fluctuation.

The bearing of these experiments upon the general nature of voluntary movement may be summarized as follows:

(1) Where a movement involving external objects is new and highly volitional, attention is normally objective, dealing with *percepts* of the *immediate*, rather than with *images* of *past* movements.

(2) Those sensations are functionally most important which reveal the present situation most faithfully in accordance with the tendencies of the individual and the exigencies of the situation.

(3) Kinæsthetic sensations become prominent, but do not *necessarily* take on guidance value, when the situation is complex and stimulating.

(4) It is only when a certain degree of skill and proficiency has been reached that imagery (in contradistinction to percepts) of any sort becomes important. This imagery was uniformly derived from the preceding perceptual experiences in making the movements (voluntarily) and *not from reflex and involuntary activities*. In other words this imagery has a *conscious* source. The experiment affords no evidence for such a thing as imagery derived from purely reflex and unconscious experiences.[1]

(5) It does, however, afford evidence that much of the control imagery as such fades away with practice and that in the last stages of a voluntary movement a complex idea of the general situation, with little or no *particular* imagery of a clear character, is sufficient to carry on a series of practiced movements. In this stage the sensations arising from the movements themselves to not necessarily give rise to perceptions, but perform their proper functions without the aid of supplementary ideational processes.

(6) There is some evidence that this complex idea or "set" of consciousness may in the case of such movements as those of type-writing be purely verbal so far as its image aspect is concerned, although the eye-closed writing gives evidence that concrete sensory processes facilitated the writing even at the end.

[1] It must not be forgotten, however, that the movement of pressing a bulb (as would in fact be true of almost all movements of adults) was not a wholly new muscular performance but rather a special adaptation of a movement already at command in a less specific form.

II. Writing Experiments, Involving Different Degrees of Practice and Volitional Control

The tests used were the following: (a) Copying a list of familiar English words. (b) Copying two-syllable nonsense words. (c) Copying German words. (d) Copying the English words while tapping with the left foot. (e) Copying the nonsense syllables while repeating the Greek or German alphabet. (f) Writing the subject's name and address upside down with the left hand. (g) Writing the name and address with the left hand while shielded from direct vision and controlled by means of the reflection of it in a mirror placed before the paper.[1]

With the exception of the upside-down writing and the mirror writing, which were not timed, one minute was allowed for each exercise. In all eight subjects (graduate students in psychology) served for these experiments, each subject taking the seven tests at least twice and in some instances three times. The general uniformity of the results warranted stopping this set of experiments with this limited number of tests.

In the discussion of the writing experiments it may be well to call attention at the outset to the physiological complexity of the movement. Physiologically writing is a highly complex activity involving the co-ordination of movements at six joints from the shoulder to the first joint of the fingers. With these movements, so intimately related to one another, must also be correlated the movements of the eyes and to an extent those of the head and body. Our problem is how these co-ordinations are controlled. It is to be observed at once that we are not immediately aware of any of the co-ordinations mentioned. It is only by reflection upon the act of writing that we become aware of them in any definite sense. Another palpable observation is the fact that writing involves fineness of movement and co-ordinations and therefore fineness of discrimination somewhere on the side of control, for it may with safety be assumed that sensory discrimination, conscious or unconscious, is directly related to accuracy and delicacy of movement and it is certainly conscious in some measure until the movement becomes habitual or automatic.

If then, with this delicacy of movement and fineness of sensory discrimination in mind, we ask what on *a priori* grounds is the sense organ that primarily controls such move-

[1] It is only fair to state that these experiments were complete before the publication of the somewhat similar ones of Dr. Downey mentioned in the preceding section.

ments, especially in its early stages, the eye at once suggests itself. In the experiments here described the tendency to use the motor cue as the focal element is nowhere in evidence except in the upside down and mirror writing. Muscular sensations are occasionally mentioned in the other tests but never reported as focal. Moreover, it is very likely that the introspective attitude was influential in rendering them focal in the tests in which they so appear. A comparison of the tests in which kinæsthetic sensations appear as focal brings out an interesting fact. When, *e. g.*, in the writing with mirror guidance, interpretation of the visual process is made necessary by the conditions of the experiment while the movements themselves are in no wise changed from normal writing, the subject falls back upon the use of motor sensations as the focal elements almost in spite of his effort to the contrary. That is, the tendency to follow *directly* the visual cue given by the mirror and thus make the wrong movements is so strong that to write correctly requires the neglect of vision until a new co-ordination is started when the mirror cue can be used directly. This, we think, shows clearly what a predominant function vision normally assumes in our writing reactions, especially when beginning.

In the upside down writing *the* difficulty was to visualize the *letters* upside down, *not* the movement nor to have an anticipatory image of how the changed movement was going to feel. This primary difficulty of visualizing the letter in the reversed position was experienced by every subject, but was met and overcome in various ways by different subjects. Some succeeded in visualizing the letter upside down, two visualized themselves as sitting "on the other side of the desk" while one thought "of how the hand should go" and of the muscular sensations when the movement was once started. Attention is called to the fact that in the mirror writing (*i. e.*, writing with work reflected in the mirror) what is being put on the paper is constantly flashed back to the eye in a reversed position, and that the *sight* of this reversed position tends immediately to reverse the movement, while in the upside-down writing the subject sees what is written *as* it is written. In the latter the vision controlling the movement is direct and correct; in the former it is indirect and reversed. In the upside-down writing the muscular sensations were theoretically radically changed from normal writing while the subject's vision of what he was doing was not interfered with, but in the reflected writing the muscular sensations theoretically were the same as under normal conditions and actually should be the same so far as the movement itself is concerned, while the subject's vision of what he was doing

was radically changed, making a condition in essentials the reverse of the upside-down writing. It is therefore clear that in writing movements the muscular element can be changed (not eliminated) with less interference with the activity than is produced when the visual element is changed.

This suggests that on the sensory side writing may be regarded as a visual-kinæsthetic activity with vision representing the extra-bodily aspect of the total process and the muscular sense the intra-bodily aspect. As a matter of fact it would seem that every new voluntary activity whose object is an extra-bodily end requires the sensory or perceptual representation of those two aspects of the process and these two only, the one representing the *status quo* of the thing being manipulated, the other that of the bodily member immediately concerned with the manipulation. Our writing experiments show that in the more highly volitional tests attention is uniformly upon the extra-bodily aspect unless conditions are such that reaction to the visual elements can take place only by way of complex interpretation. The study of the cases of anæsthesia (to be described later) will show that the muscular sense normally serves the function of giving the *status quo* of the bodily member, but that in case of tactual-kinæsthetic paralysis vision is called upon to perform this function. These facts agree with the facts obtained in the present study. Moreover the facts there obtained agree also with those obtained in the writing experiments in this, that in the automatization of voluntary movement the extra-bodily elements drop out of consciousness before those representing the position of the member in movement. This is abundantly illustrated by the fact that every experiment with the upside down and mirror writing shows attention to the result, and not only that, but *visual* attention wherever it is practically possible. On the other hand in those experiments in which the movements and the manner of control were familiar but the copy unfamiliar and meaningless, as in case of the nonsense syllables, there was a minimum of attention to the result. The same thing is true of copying nonsense syllables and repeating the Greek and German alphabet. In this case attention fluctuated from the copy to the alphabet but not to the result put on paper. In both these cases the handwriting suffered somewhat, as is shown by comparison with the other experiments in which there was visual attention to the result. It suffered not only in the large co-ordinations such as following the line, spacing, etc., which involve a spatial reference for which the muscular sense is inadequate, but also, in instances in a marked degree, in the details of the movements which apparently have "gotten into our muscles" and which

in normal writing under visual guidance receive practically no attention. Ordinarily we write with the eye focussed upon the paper at or near the point of the pen while attention may be, and usually is, far away from the movement as such. In fact, consciousness of the finer aspects of the movements involved seems to be next to nothing, yet the slight peripheral visual consciousness (it cannot be called attention) is evidently of great value in furthering the co-ordinations.

In such controlled reactions as copying words under conditions involving varying degrees of difficulty there are three things we *may or must attend to or be conscious of*, depending upon the conditions and the difficulties involved. These are the copy, the result, and the position and movements of the bodily parts active in the production of the movements. Attention to, or consciousness of, the first two is always visual. It is moreover highly probable that in the *early* stages of writing the visual *attention* fluctuates between these two and the third. The position is, however, never normally *attended to* without resulting in distraction. Of these three factors the *details* of the result, as already shown, drop out of consciousness comparatively early. It is precisely these details which in the early stages of learning to write give the most difficulty and which are attended to most closely. It is here tentatively suggested that this principle holds for a large range of our acquired activities. This much seems clear, that consciousness of position either by means of the resident sensations or by means of the visual and remote sensations is necessary long after the details of the result have dropped out. It is highly probable that in coördinations that are far removed from our inherited reactions, like writing, consciousness of position can never drop out with impunity. The long continued practice that is necessary to reestablish walking (which at most is only partially a learned reaction) without the aid of the eye, in cases of sufficient tactual and kinæsthetic anæsthesia to destroy the sense of position, is strong presumptive evidence in favor of such a view.

Two other considerations of interest with reference to the automatization of writing movements are the behavior of inner speech and the appearance of more or less irrelevant imagery as the process becomes easier. The inner speech, more generally mentioned than any other one thing, is universally present in the copying of nonsense syllables and German words. The introspections contain only two observations of it in the upside down and mirror writing and these by the same subject. But this fact, we believe, does not justify the conclusion that these instances show that it was not generally present. It seems probable that if present, its infrequency, due to the slowness of the

writing and the objective nature of attention, might easily account for its being overlooked in the introspections. This much, however, seems clear, that inner speech rises into distinct consciousness whenever the *meaning* of what is being written is not at once present. Whenever the ideational processes resulting in or constituting meaning are blocked, inner speech at once comes into clear consciousness. And probably also when anything hinders attention to the writing. But, although the introspections are inconclusive upon this point, there are indications that, in spite of its greater prominence, inner speech is little more than an accompaniment when the copy and conditions are unfamiliar and difficult and that it is more distinctly a cue when the copy is familiar and the conditions easy. Evidence for this is found in the constancy with which the eye is kept upon the copy when the former conditions prevail and its desertion of the copy in the latter conditions. That is, when the eye has to be kept upon the copy the writing becomes more nearly an act of drawing; in fact that is what it amounts to in the upside-down writing where the primary difficulty is one of visualization.[1] If this view is correct, it follows that inner speech unaccompanied by ready meaning, does not in itself serve as a cue. The inner speech, in this case is probably primarily of service in the development of meaning and not in the direct control of the movement. More exactly it is not so much a control factor as an initiatory element; it is the element with the appearance of which meaning is primarily developed.[2]

The facts brought out in this set of experiments tend to show in connection with the preceding experiments, that in a general way the content of consciousness *changes* rather than diminishes

[1] The copy was, of course, *not* presented upside-down.

[2] It is, however, not to be assumed that the same explanation is offered for the function of the auditory image (which is always present in inner speech and constitutes an aspect of the latter) in the case of actual speech. That the auditory image has a direct control over speech regardless of meaning in any specific sense is readily demonstrated by the child's ability to enunciate more correctly than most adult beginners the sounds of an unknown language. That the auditory image is *primary* in such control is also evidenced by the methods employed in teaching deaf mutes to speak. *Cf.* Farrar: Arnold's Ed. of the Deaf, pp. 127-128. This position is uniformly supported by reports of methods employed in teaching deaf mutes to speak at several institutions for the education of this class of defectives. This statement from one of them is illustrative. "Absolutely deaf children always remember the visual appearance of the word on nose and lips and associate this with the feeling produced in them when they give the same sound. Only the blind deaf make a constant practice of touching another's lips. Those who have some hearing left, probably have an idea of the sound of the word when they speak it. This largely takes precedence of all other impressions."

as movement becomes easier. The decrease of associations and the growing absence of irrelevant imagery as the subject goes on from the copying of simple English words up to the upside-down and reflected writing (in which they do not occur at all) shows that as attention becomes more necessary and more concentrated the range of consciousness narrows; and the converse is also true, as attention becomes less concentrated, the range of consciousness becomes wider, and more or less extraneous imagery appears. It is therefore clear that in case of easy movements attention responds more readily to other stimuli and as a consequence becomes a mixed process, including, so far as the movement is concerned, both relevant and irrelevant elements. It would therefore be easy to fail to see the woods because of the trees and report no imagery when in reality it may have been present. As a matter of fact there are here two things to be kept distinctly in mind; the first is that in highly voluntary movement, but not too difficult to permit *Zerstreutheit*, attention is intense and consciousness narrow, and therefore the imagery or sense data are strictly limited *at any given pulse of attention*. The second fact is that in well learned and facile reactions the attention to the activity is minimal and the range of consciousness correspondingly wide. Strictly speaking it is therefore not true, at least from the point of view of the objective movement which it produces, that consciousness is always a unitary process, for clearly the most important elements in the configuration of consciousness may not always participate in the production of a specific movement.

III. Anatomical, Physiological and Pathological Data

It is the purpose of this section to review, as succinctly as the complexity of the subject will permit, the leading anatomical facts and physiological experiments, together with a number of pathological cases of anæsthesia, that have a bearing upon voluntary movement.

1. The Anatomical Facts as reflected in Recent Neurological Literature.

Recent neurological studies on the relative number and distribution of sensory and motor fibres in the peripheral nerves throw a certain light upon the relation of sensory impulses to voluntary movement. Donaldson has pointed out that, "Taking the central system segment by segment, the sensory nerves are more numerous and have a greater area than the motor. In man, as we pass cephalad, the superiority of the sensory nerves becomes most marked,—"(Growth of the Brain, p. 196.) Ingbert counted the nerve fibres of the left dorsal roots of a man weighing 180 lbs. and found the total number for the left side to be 653,627 which would give a total, for both sides, of

1,307,254, assuming that the innervation is the same for both sides. Ingbert also counted the fibres in the ventral roots of the same cord and found the total number, for both sides, to be 407,400. This would make the ratio of sensory to motor greater than 3:1 and at once suggests James's figure of a "funnel" with the big end representing sense processes and the small end movements.

Of still greater interest from a psychological point of view is Ingbert's table showing the number of fibres for each spinal segment. The curve for these figures shows in a striking manner that the number of fibres and the area of the nerves representing sensation from the more mobile and voluntarily controlled parts of the organism, particularly the arms, are very much greater in proportion to mass than they are for the less controlled organs. While there are no data demonstrating it in detail, roughly and in general, at least, one may say that sensory innervation is directly proportional to mobility and voluntary control. This position is supported by the experiments of Van Biervliet on "*Le toucher et le sens musculaire.*" (L'Année Psy., 13, 1906, pp. 114-121.) Van Biervliet found that sensibility to touch is directly proportional to the mobility of the organ and that sensitivity increases with practice and skill in control.

Further light is thrown on these anatomical facts by Head's recent study of peripheral sensibility. ("The Consequences of Injury to the Peripheral Nerves in Man." *Brain*, 1905, pp. 116-338, and "The Afferent Nervous System from a New Point of View." *Ibid.*, pp. 99-115.) Head distinguishes three forms of peripheral sensibility:

I. "Deep sensibility, capable of answering to pressure and to the movements of parts, and even capable of producing pain under the influence of excessive pressure, or when the joint is injured. The fibres, subserving this form of sensation, run mainly with the motor nerves, and are not destroyed by division of all the sensory nerves to the skin." (p. 111.) "Deep sensation is not materially affected by the destruction of all the nerves to the skin, and it must reach the central nervous system by fibres that run in other channels than the so-called sensory nerves." (p. 215.)

II. "Protopathic sensibility, capable of responding to powerful cutaneous stimuli, and to the extremes of heat and cold. This is the great reflex system producing a rapid, widely diffused response, unaccompanied by any definite appreciation of the locality of the spot stimulated." (p. 111.)

III. "Epicritic sensibility, by which we gain the power of cutaneous localization, of the discrimination of two points, and of the finer grades of temperature, called cool and warm." (p. 111.)

In an article "On the Anatomical Constitution of Nerves of Skeletal Muscles." (*Journal of Physiology*, Vol. 17, pp. 211-258.) Sherrington reports a study of sensory and motor fibres supplying different muscles. He says: "Taking the whole series together, the average proportion of the afferent fibres to the total myelinate fibres in the nerves of the muscles examined proves to be a little less than a half (49%). The proportion of afferent fibres to the total myelinate fibres ranges from a little more than a third in some muscular nerves to a full half in others." (p. 229.) "In the nerves to some muscles the afferent fibres are as numerous as the efferent. It is probable that the very largest cells in the spinal ganglia belong to some of the nerve-fibres of the muscle spindles. Probably in every spinal ganglion a number of the nerve-cells belong to the sense organs of muscles." (The Spinal Animal. *Medico-Chirurgical Translations*, Vol. LXXXII, p. 455.)

Dunn caused all the motor nerves to the legs of a frog to degenerate and "found that there remained an ample supply of medullated fibres to the muscles. These represent from 15 to 30 per cent. of the fibres going to the muscles."

Assuming that the relative motor and sensory nerve supply to the voluntary muscles of the guinea pig and white rat is approximately the same as it is for the animals studied by Sherrington and Dunn, we have in their results an excellent neurological basis for the psychological results obtained by Small and Watson with the rat and Allen with the guinea pig. (Watson, *Mon. Sup., Psy. Rev.*, May, 1907. Small, *Am. J. Psy.*, Vol. 12, pp. 206-239. Allen, *Journal Comp. Neur. and Psy.*, Vol. 14, No. 4.)

Both Small and Watson, especially the latter, found that kinæsthetic processes play a highly important, if not a preponderating rôle in the controlled movements of the rat when learning to run the maze. Allen found that in case of the guinea pig "vision is an important element" but that the "labyrinth is not learned solely, or even largely, in terms of tactual sensations." Her conclusion is that "kinæsthetic sensations are of great importance in the recollection of a path." (*Op. cit.*, pp. 330, 336 and 337.) Yerkes working with the frog came to practically the same conclusions, finding that "beyond question vision and the direction of turning were all important factors in the establishment of the habit." (*Harvard Psy. Stud.*, I, p. 579.)

In connection with what Allen finds to be true with the guinea pig, it is interesting to recall that frequently in human cases of locomotor ataxia the cutaneous sensibility escapes injury while the muscular sense always suffers more or less and

with a corresponding effect upon co-ordination. Head's cases on the other hand clearly illustrate that the loss of *tactile* sensations alone in man has little or no effect upon voluntary movement.

2. Physiological Experiments.

In order to determine the effect of the loss of "resident sensation upon movement, Mott and Sherrington working on the monkey severed the dorsal roots on one side of the cord supplying the arm and leg with sensory innervation, viz., the 4th cervical to the 4th thoracic inclusive, and the 2d to the 10th post-thoracic inclusive. The results are described in their own language as follows: "From the time of performance of the section onward as long as the animal may be kept [they kept them about four months] the movements of the hand and foot are practically abolished. On the other hand, the movements of the elbow and knee, and especially the movements at the shoulder and hip, are much less impaired. If the feeding time be deferred, and an animal, in which the apæsthete limb is an arm, be tested by offering it fruit after the sound arm has been secured behind the back, there is no attempt to use the apæsthete limb for reaching the food, but the neck is thrust forward in order for the mouth to seize it." One monkey tried to take food with the apæsthete foot but failed,— "the digits were not moved." "The defect in motility increases from the attached base to the free apex of the limb; so that, for instance, while comparatively slight at the hip, it is successively greater at the knee and ankle, and greatest (amounting as regards volition, to absolute loss) in the digits." The authors conclude that volition "has been absolutely abolished by the local loss of all forms of sensibility." (*Proc. Roy. Soc.*, Vol. 57, pp. 481 ff.)

Bastian, on the other hand, while accepting these facts criticises Mott and Sherrington's interpretations. *Brain*, Vol. 18, pp. 609 and 615. Bastian argues that limb movements may be paralyzed or rendered defective in two ways: (a) by organic lesions (b) by functional defects. These functional defects are of two sorts: in the one case the "seat" is cerebral, in the other, spinal. He says that "in cases of complete hemianæsthesia due to lesions or functional defects in the posterior part of the internal capsule, there is not only no paralysis, but little or no impairment in the ability to perform, under visual guidance, even the most delicate movements with the apæsthete limbs." As is well known, Bastian holds that there are no motor centres strictly speaking, that what we call motor centres are essentially kinæsthetic centres and that impulses have to pass through these centres before a movement can be made, but that these impulses may originate in the auditory centre

as in speech or in the visual centre as in hand movements, and therefore there may be controlled movements without kinæsthetic sensations from the limb to be moved.

Sherrington, however, writing after further experimentation bearing upon the relation of sensation to movement seems to modify somewhat his original rather rigid and sweeping position. He writes: "It is found that the destruction of sensitivity in particular regions brings about objectively observable disturbances of movement." . . . "the effects of apæsthesia upon the musculature of the part are three—(1) paralysis, (2) ataxia, (3) atonia." (*Proc. Roy. Soc.*, Vol. 60.)

Munk repeated the experiments of Mott and Sherrington and at first obtained the same results, but later found that monkeys recovered to a degree their ability to use the hands that had been rendered anæsthetic. These movements, however, were always inaccurate and exaggerated. Moreover only single voluntary movements could be made at all. Munk's animals at first dropped food placed in the anæsthetic hand but later learned to grasp it and carry it to the mouth. After getting it to the mouth the monkey at first removed the fingers from the food with his teeth but after some practice learned to let go "actively" when the hand reached the mouth. Then instead of placing the food in the monkey's hand, Munk simply presented it to him. With the sound hand tied behind him the monkey after experience learned to take the food from Munk's hand and carry it to his mouth with the anæsthetic hand.

What Munk specifically denies in Mott and Sherrington's deductions from these facts is that the entire sensory mechanism is and must be operative in voluntary movements, that the entire sensory path from the periphery to the cortex is necessarily active in volitional control. Munk points out that the only movements that are entirely and permanently destroyed are the reactions that normally take place to an immediate stimulation of the member concerned. All other movements which the extremity normally makes are more or less defective because the "*Einstellung der centralen Organe von welchen die Bewegungen der Extremität herbeigeführt worden, verändert ist. Die Störung ist immer desto grösser, je mehr Muskeln oder Gleider der Extremität an der Bewegung beteiligt sind.*" The important differences between Mott and Sherrington and Munk appear to lie in the fact that the former seem to regard kinæsthetic elements as the essential sensory elements in the voluntary arc, while the latter holds that any sense elements, visual, auditory, etc., will serve the same purpose quite or nearly as well in the absence of kinæsthetic elements, especially after practice.

It will be recalled that Sherrington found that in the spinal frog "the initial posture of the limb distinctly affects the character of the reflex movement—even in the absence of cutaneous organs." This fact, together with Munk's results and criticism of Mott and Sherrington, takes us again to Judd's position that in the animal relatively low in the phyletic scale the kinæsthetic areas play a more important function than they do in the higher animals for the reason that in the latter the special senses have become more highly differentiated and have accordingly, to a degree at least, usurped the original primacy of kinæsthetic centres and therefore play a more important part in volitional activity. However hypothetical Judd's position may appear, it certainly possesses the advantage of facilitating interpretation, an advantage which warrants its application. If we assume that the original undifferentiated form of sensation is of the tactual-kinæsthetic type and that from this original type all other forms of sensation have been gradually differentiated, it is clear that in animals low down in the scale of evolution the original type of sensation must necessarily perform the important function of *the* sensory cue for voluntary movement. On the other hand, in animals high in the same scale the other sense processes are so highly specialized and developed that, when measured in terms of relative discrimination, they far surpass the original type from which they took rise, and may now play the principal rôle in voluntary action. Moreover if in making a new and conscious adaptation—which involves discrimination and choice and therefore voluntary movement—the important thing is the correct grasp of the situation rather than the consciousness of the movement as such, then it also follows that the sense organs of later development naturally play a primary rôle for the reason that their discrimination is finer, and for the additional reason that they act at a distance.[1]

(3) Pathological Cases. Disease has done, not infrequently, what is impossible to experimentation upon human beings; it has destroyed the sense processes, and given us the general relation of these processes to voluntary movement in very much the same way as the physiological experiments of Mott and Sherrington and Munk reveal them in the case of the monkey. It is therefore in place to review here a number of typical cases of anæsthesia and to attempt an interpretation of their bearing upon voluntary movement. One naturally begins with Strümpell's celebrated case. Of the extent of this boy's anæsthesia James says that he "was totally anæsthetic without and within

[1] *Cf.* Sherrington: The Spinal Animal (*Medico-Chir. Trans.*, Vol. LXXXII, p. 475.)

save for the sight of one eye and the hearing of one ear." (Principles of Psy., Vol. I, p. 376.) It appears, however, from Strümpell's own account of the case quoted by James, that in "violent forced hyperextension of the joints, especially of the knees, there arose a dull vague feeling of strain, but this was seldom precisely localized." (Prin. of Psy., Vol. II, p. 489.) These poorly localized, kinæsthetic sensations seem, however, to have been of some service, for Strümpell tells us that with his eyes closed, the boy could readily raise his arm at command. Another anæsthetic case of Strümpell's is cited by James in which "The arm could *not be moved at all* [italics James's] unless the eyes were opened, however energetic the volition." (Prin. of Psy., Vol. II, p. 491.)

In "Ein Fall von aphasischen Symptomen, Hemianopsie, Amnesthetischer Farbenblindheit und Seelenlahmung, (*Archiv ür Psychiatrie und Nervenkrankheiten*, Vol. 25, 1893.) Bleuler describes a case of total anæsthesia on the right side. Of its effect upon movement he says: "If the patient does not see his right arm, he not only does not know where it is, *but cannot innervate it at all.*" In summing up his observations upon these phenomena Bleuler says, "It is known that patients who are not at all aware of the effects of their muscular innervation are no longer in a position to make spontaneously purposive movements." He cites the case of Niemeyer and Späth whose patient, an "Anæsthetische Tabetiker," fell down while standing or sitting if he closed his eyes. He cites also the case of Ziemssen and Heyne, whose patient was entirely anæsthetic with the exception of his face and hearing, and who could not speak when his ears were stopped.

A. Pick describes a case (Ueber die Sogenannte 'Conscience Musculaire,' *Zeit. für Psy. und Phys. der Sinnes*, Vol. 4, pp. 175 ff.) in which the patient (a young woman) presented 'eine nahezu die ganze Körperoberfläche einnehmende Anästhesie und Analgesie.' On the right side there was complete loss of both superficial and deep sensibility. In all experiments involving hand movements this patient sharply fixated her right hand, which was completely anæsthetic. This fact, Pick points out, does not agree with Binet's (apparently *a priori*) contention that, other things being equal, attention would be fixed by preference upon the sensible half of the body, because this is the only part which gives the muscular sensations during movement. Pick's patient was unable to hold the left arm horizontally extended and at the same time make the movements of playing the piano with the right. She could, however, hold the right hand extended and make such movements at the same time with the left with-

out serious disturbances. If with eyes closed, the patient is asked a question she merely moves her lips in reply but upon opening her eyes declares she answered the question aloud. If her ears are closed and she is handed a written question she again merely moves her lips in reply, declaring when her ears are opened that she replied aloud. If she is requested to open and close her hands she accomplishes the movements by fixating the right hand. But if the right hand is placed outside the narrow field of vision the movements cease. Two interesting facts appear in this case: (a) when the sense processes are reduced to a certain minimum the movements called for, if executed at all, are reduced to a certain minimum of intensity. (b) In the two hand movements the left hand is controlled by means of the "resident" sensations while the right hand is controlled by means of vision or "remote" sense processes. In other words, either resident or remote sensation is essential for the control of each arm, the coördination (apparently) taking place when the one is controlled by "resident" and the other by "remote" processes.

Pick also cites the cases of Duchenne who observed three patients with total loss of sensibility on one side. Duchenne found that they were unable to move the anæsthetic members without the aid of vision. Both Pick and Duchenne explain their cases wholly in terms of attention. This explanation may be criticised on the following grounds: (1) Attention is not a psychic entity, as these authors appear to imply, but only a state of psychic processes. (2) As a state of psychic processes attention is, to quote Pillsbury, merely "an increase in the clearness of one idea or group of ideas at the expense of others." (Attention, p. 11.) (3) To attend there must be something to attend to, which is what is wanting to the anæsthetic. That attention is an important factor in all forms of voluntary movement would probably be conceded by every competent observer, but that attention cannot create sensations and ideas but only render them conscious, or better, more clearly conscious, must be *conceded with equal readiness*. And what the facts show in these cases is *primarily* a loss of sensations and ideas normally functional in voluntary movement.

Bleuler also rejects the explanation in terms of attention on the ground that his case showed no marked disturbances of attention *when getting sensations*. In place of this explanation Bleuler offers the following. He points out that we never take notice of the particular muscles concerned in making movements. "Unser bewusster Wille innervirt also nicht bestimmte Muskeln, sondern er führt mit den Gliedern bestimmte Locomotionen oder bestimmte Thätigkeiten aus."

"When we reach for an object we move the hand to the right or left as may be necessary, but in turning the hand to the right the opposite muscles are used from those used in turning to the left. But in all such movements the conscious process, the desired activity remains the same." Bleuler holds, too, "gewisse Kenntniss der Ausgangsstellung ist also zur Ausführung der meisten bewussten Bewegungen unentbehrlich."

Berkley reports "A case of General Cutaneous and Sensory Anæsthesia" (*Brain*, Vol. 23, pp. 111-138), in which, besides total blindness and partial deafness, there was almost total loss of the two forms of sensibility called by Head Protopathic and Epicritic but with only partial loss of "deep" or muscular sensibility, *i. e.*, there was total loss of "thermic, pain, olfactory, gustatory, equilibrium, pressure and weight sensations," and almost total loss of the visual but only partial loss of the muscular sense. "With auditory perceptions a progressive dulling could be noted." In fact "none of the special senses or cutaneous sensations remained wholly uninvolved." Considering the degree and extent of anæsthesia, this case presents two striking considerations: (1) "The musculature, while responding to the will, did so in such a feeble manner that the patient was incapacitated from helping herself to any extent. Thus the dynamometer, when taken in the hand and squeezed, was so feebly compressed that the indicator showed no movement of the dial, though the woman exerted every effort in the trial." This in spite of the fact that both nerves and muscles responded promptly to the galvanic and faradic currents, and in spite of the fact that the autopsy revealed no emaciation. (2) The second fact to be noticed in this case is that "throughout the long course of the illness there was never the slightest departure from normal mentality on the part of the patient." It is therefore clear, that so far as this case is concerned a general loss of sensibility affects voluntary movement more seriously than it does the ideational processes.

Spiller reports a case of anæsthesia in which a loss of muscular sensation resulted in inability to control the member unless it was kept in the field of vision. The "sensations of touch, pain and temperature are diminished in the left, but not to the same degree as are the sense of position and stereognostic perception." ("Separate Sensory Centres in the Parietal Lobe for the Limbs," *Journ. of Nerv. and Mental Diseases*, Vol. 33, pp. 117-121.) The defects of movement accompanying these sensory disturbances are described by Spiller as follows: "The movements of the left upper limb are awkward, although the limb can be moved freely at all

parts, and is not weak. The patient is unable to button his coat with his left hand alone when his eyes are closed, because of incoördination of the fingers, but can button it promptly with his right hand." (pp. 119-120.)

F. Pick describes a case which, besides other complications of partial anæsthesia, presented total ("constant totale") anæsthesia of the left side. While unable to imitate with the right leg passive movements of the left (anæsthetic), this patient could under visual guidance readily imitate with the left leg passive movements of the right. With the aid of vision he could, though hesitatingly, raise the left arm, but with eyes closed he was entirely unable to do so. However, if one passively bent the right arm (the eyes being closed) and repeated the command to bend the left or anæsthetic arm, the command was "promptly" obeyed and the movement made "in der gleichen Weise." (Ueber Transcorticale Störungen des Bewegungsapparates, *Deutsches Archiv für Klin. Med.*, Vol. 76, pp. 144 ff.)

Hoppe describes a case of almost complete anæsthetic paralysis of the right arm, together with "well marked amnesic aphasia," besides other more or less complete disturbances of sensibility. (Soul Paralysis, *Jour. of Mental and Nerv. Diseases*, Vol. 32, pp. 145-159.) With reference to the sensibility of the arm the author says "the muscle sense and sense of position of limb" are "almost absent." Muscular power, however, is "almost normal." The effect of anæsthesia upon movement is described as follows: "The arm is completely paralyzed, has not moved at all during the four weeks since onset of trouble. The arm is flaccid, relaxed, reflexes are absent, upon being requested to move the finger or hand, was not able to make the slightest movement, although she made an attempt to do so, showing that she understood the request. Very often, later on, a request to move the right hand was answered by the movement of the left hand. If the patient, however, was told to watch the doctor's hand and then to repeat the movement, the movement could be executed at once. Then the apparently completely paralyzed hand was made to extend and flex the fingers and thumb, to spread them wide apart, and to flex and extend the hand on the second day. Inside of a week all the normal movements of the arm and fingers—flexion, extension, moving of arm and placing hand on head and elevating shoulder could be done, usually only after she first saw the movements executed by the physician, *and only then when she was told to watch the movement closely.*" (pp. 147-8. Italics mine.) With reference to the arm, Hoppe's résumé of the sensory and motor disturbances in this case is as follows: ". . . right sided diminution of sense of

touch, pain, muscle sense, and sense of posture. Condition of motor function: an absence of real paralysis in right arm and leg, but the arm is not used spontaneously for voluntary acts: lies as if paralyzed along side of patient; arm is used for reflex acts, like scratching, and for unconscious acts, like bracing herself when arising from a sitting or recumbent position to a standing one. When shown how to make a movement, and especially when the movement is made passively in the arm several times, the patient is able to repeat it perfectly. These are then apparently normal and not clumsily made *nor is it necessary for patient to control these movements with her eyes.*" (pp. 148-149. Italics mine.)

Here we have a case which on the mental side illustrates three sorts or grades of movement:

(a) The highly volitional. Because of amnesia and lack of practice (it will be recalled that for four weeks the arm was not moved) this patient had apparently entirely forgotten certain arm and hand movements. These movements were made again by means of visual sensation from, and attention to, similar movements first made by the physician and also by means of visual sensation from, and attention to, the arm itself while the movements were being made.[1]

(b) The practiced voluntary. After practice, it was observed, the patient could make these arm movements without immediate visual control. (It is, however, always necessary to remember that the arm was not completely anæsthetic.)

(c) The reflex instinctive (?) These movements ("scratching," "bracing," etc.) did not require a period of learning and practice before they could be made without imitation and visual control, but appear to have been carried over into the anæsthetic condition from the normal condition. For these the remaining kinæsthetic sensibility seems to have supplied a sufficient sensory cue for their ready performance.

F. Müller describes a case of right-sided anæsthesia so nearly total that the patient could not distinguish passive movements

[1]Another instructive case has been kindly supplied me by Dr. Fairbanks of N., Mass. The patient, a young woman who suffered from spinal meningitis when ten years old, has lost sensibility in the fingers of both hands and cannot do anything with her fingers unless she can see what it is; for example, she can button or hook a garment that opens in front but not one that opens in the back. She can put her hat pins in if she is in front of a mirror. After anæsthesia appeared (which was not until about fifteen years of age) the attending physician recommended horseback riding, but this had to be given up because the patient could not hold the reins unless they were constantly kept in the field of vision. This case is particularly significant, because there are no other complicating disturbances, the patient being in all other respects highly efficient.

except when very intense. "Die aktive Bewegung der Hand und der Finger war nicht vollkommen aufgehoben aber ungeschickt, alle feineren Bewegungen waren unmöglich." (p. 403, Ueber Störungen der Sensibilität bei Erkrankungen des Gehirn, Klinischer Vorträge, Serie XIV, Heft 4-5, pp. 337-451.) In this case, too, visual sensations from the fingers were necessary for use of the finer muscles. But the significant thing in this case is that while at the end of two years the patient (an intelligent person) could not tell the position of his arm with eyes closed, he had nevertheless learned to use his hand with some facility.

The case cited in the note above (anæsthetic for 15 years) tends to show that when the anæsthesia is total no amount of practice will bring back control of the finer muscles without visual sensations from the member. The cases of Müller and Hoppe also tend to show that when local sensibility is still present, though so reduced that vision must be employed for a long time, a slow process of training under visual control may again re-establish control without visual sensations. This is well shown by Goldscheider in his "Anleitung zur Uebungs-Behandlung der Ataxie" in which he gives in great detail many devices for the re-establishment of walking and of hand and arm control, ultimately without visual guidance. It appears, however, from Goldscheider's account that there is strong presumptive evidence that none of the cases succeeding without visual assistance are totally anæsthetic. The fact seems to be that in cases successfully treated there is a modicum of sensation left which attention gradually gets hold of, and thus gradually regains control.

(4) Summary and Conclusion. The study of the proportion of sensory and motor fibres in the higher vertebrates including man shows not only a great preponderance of sensory fibres in general, but also a rich supply of sensory fibres to the voluntary muscles. The curves giving the distribution of the number of sensory and motor fibres, for the ventral and dorsal spinal roots show clearly that in a general way at least there is a marked increase in the number of sensory fibres supplied to regions whose muscles are most used in controlled activity.

Correlated with these facts are the studies of animal activity tending to show, in some instances by a process of elimination, that the kinæsthetic processes play an important part, if not a predominant rôle in the controlled activities of lower animals. Sherrington appears to refine upon this position somewhat by holding that those sensations giving the location of the member are *the* essential ones. He says: "It is found that kinæsthetic sensations of the movement to be acquired or controlled, though helpful, are less important than the resi-

dent sensations from the part in its 'resting' state. These latter, with the power to focus attention upon them, appear to be a most necessary condition for the acquirement of control. And in the monkey, voluntary control of a limb is largely lost when the limb has been rendered apæsthetic." (The Integrative Action of the Nervous System. p. 390.) Other physiological experiments support the same thesis. Munk's experiments tend to show, however, that in case of the monkey after loss of kinæsthetic sensibility there may be a process of relearning under guidance of vision.

Practically all the pathological cases that have been reviewed, tend to support the interpretaton of Munk that the kinæsthetic motor arc is not the only one whereby voluntary control is effected.

Lastly, the anatomical facts, the physiological experiments and all the cases of complete kinæsthetic anæsthesia tend to show that voluntary movement, like all other forms of movement, rests upon the existence of a sensory-motor arc; that *without sense processes relevant to the situation*, purely ideational processes, however important they may be as elements in the total mental complex functional in volitional acts, are nevertheless by themselves entirely incompetent to initiate and control such acts. Of all the mental processes that *may* function in consciously controlled acts the *sine qua non* appears to be *sensation*.[1] The facts presented show not only the necessity of centripetal impulses, but the necessity of *sensation*, at least in all forms of voluntary activity not thoroughly practiced and habitual. The relearning under the guidance of vision of lost movements on the part of Munk's monkeys, the cases of Müller, Hoppe, Spiller and Fairbanks, together with the methods used by Goldscheider and others, illustrate this abundantly. Centrifugal processes are of course necessary, but in and of themselves not sufficient. Some of the cases show that even a modicum of sensation from the member to be moved is not sufficient for control and must be supplemented by vision. The fact seems to be that there must be a sufficient amount of sensation to give rise to at least a peripheral consciousness of the member, which so far as the centripetal process is concerned is capable of becoming focal and perceptual at any moment.

IV. The General Theory of Voluntary Movement.

That psychology is in need of a more exactly defined terminology must be evident to every thoughtful reader of its

[1] By this term is meant a *conscious, but not necessarily a focal* process.

literature, particularly of that bearing upon movement and the affective processes. There is, however, another sense in which the psychology of movement is in need of a definition. It needs a descriptive and analytical definition of the various kinds and grades of movement as a basis upon which the completer analysis of the processes themselves may proceed. Of course no definition can be *a priori*, but after a certain degree of analysis has been reached it becomes imperative for further work. That the psychology of movement is in need of such a descriptive definition becomes apparent when we consider the processes in terms of which some of the standard discussions describe voluntary action.

Stout tells us that "a volition is a desire qualified and defined by the judgment that, so far as in us lies, we shall bring about the attainment of the desired end." (Voluntary Action, *Mind*, N. S., Vol. 5, p. 356.) He goes on to say, "When attainment is judged impossible, volition in the full sense cannot exist." (*Ibid.*, p. 356.) "In a perfect volition, opposing impulses are not merely held in check; they are driven out of the field. If they continue to exist they do so as external obstacles to a volition already formed. They are no longer motives. They are on the same footing with any other difficulty in the way of attainment." (*Ibid.*, p. 357.) His general position is that "it is the *cognitive* side of our nature which gives determinate character to the conative." (*Ibid.*, *p.* 356.)

It will be seen that Stout's definitive statements are quite opposite to Wundt's who holds that volitional processes are essentially always *affective* processes (Affecte) (Phys. Psy., 5th ed., Vol. III, p. 244). These feeling processes (Gefühlsvorläufe) are, however, always bound up with a more or less clear sensation or ideational process (*Ibid.*, p. 242). But the primal necessity for a volitional process is an impulsion of some sort or "so-called motive." (*Ibid.*, p. 243.) Still another characteristic of a voluntary act according to Wundt is its duration; it is "never a momentary act," but has a characteristic duration in which there takes place a change of feeling. (*Ibid.*, p. 243.) So nearly alike are volitional and affective processes in Wundt's descriptive definition that in their beginning stages it is impossible to distinguish between affective and volitional activities. The distinction appears only later in the "*Endstadium*" and is to be found in the peculiarly sudden release or change of the affective processes. It must, however, be remembered (and this is important for our own description) that the 'release process' or "*Endstadium*" involves also accompanying ideational processes. (*Ibid.*, p. 245.)

Külpe (Outlines, pp. 265-267) does essentially the same thing, making his brief analysis of voluntary movement fall

within his discussion of the Feelings. He explicitly denies the existence of an "elementary quality" as the distinguishing characteristic of voluntary action and holds that effort is the "one definite phenomenon" which fundamentally characterizes such action. This effort, he goes on to say, "appears to be a complex of more or less vivid organic sensations, composed of tendinous (strain) and articular sensations, peripherally and centrally excited." Külpe dismisses the subject with a brief general description and nowhere tells us in precisely what sense he is using the term voluntary or what the distinguishing marks of the act are, other than that it is markedly the feeling of effort which is a complex of organic sensations. But, as Stout has pointed out, the feeling of effort may "belong as well to the antagonistic tendency which renders the voluntary attitude abortive." (Voluntary Action, *Mind*, N. S., Vol. 5, p. 354.) Moreover the feeling of effort when reduced to the elements of organic sensations is theoretically hardly to be distinguished from emotion when the latter is reduced to its elements, at least according to the prevailing "peripheral" theory. The concept of effort is too vague to be used as the distinguishing mark of voluntary action. Any attempt at complete analysis of the mental processes concerned in voluntary movement is bound to find itself occupied with the cognitive aspects of these processes. It may be urged that this is an objection based upon mere convenience. Even if this were true, it would appear justifiable. Science must everywhere push its analysis in terms of that which most readily lends itself to analysis, provided always, of course, that the analysis does not proceed at the expense of truth and completeness.

The objections urged against the feeling of effort in particular hold also with reference to the feelings in general as distinguishing features in terms of which to analyze and describe our voluntary activities. Against the description of voluntary movement in terms of feeling the following arguments are urged: (1.) Feeling is never the fundamental process in a complex and highly voluntary activity. *Functionally* it is of great importance as a part or aspect of the motive in every voluntary movement from the simple impulse to the volitional act. But, as Titchener has clearly pointed out, the motive is complex, made up of sense or ideational processes on the one hand and affective or feeling processes on the other. But—and this is the important point—the sense or ideational process is always the *conditioning* process, *i. e.*, its nature and meaning always determine the nature and intensity of the feeling.

(2.) Biologically considered the feeling as a psychic process, functional in a controlled response, is entirely too subjective, too vague, too little informational to be regarded as the fun-

damental process in effecting voluntary control. The fundamental process is the one that best reveals the situation to which the response is made. For this reason the term "cognitive" is significantly appropriate to the sense and ideational factors. They reveal the situation and so afford a basis for successful reaction. Organic sensations at best tell us only of the subjective; but voluntary movement, in the last analysis, finds its cues and control factors (not necessarily its entire motivation) in external conditions. One might even go so far as to say that every movement that takes place wholly on the basis of the subjective and without any regard to objective or extrabodily conditions of a sensory or ideational nature is essentially of the reflex or automatic type.

(3.) Common observation teaches also that the predominance of purely subjective elements is always an interference in volitional performances. Feeling doubtless plays a highly important function in the *initiation* of many voluntary activities but the position taken here is that *voluntary movement is not a matter of initiation of movement nor a peculiar species of movement per se, but is essentially a form of control and in this respect alone differs primarily from other kinds of movement.* So far then as voluntary acts are concerned, the initiation of movement may be assumed; it is provided by the physical and mental constitution of the organism which, in the psychology of the individual, must be assumed. Biologically voluntary movement is a peculiarly *individual* form of adaptive control. Perhaps it would be better to say that it is peculiarly individual just because it is adaptive to conditions that are nonracial and therefore individual. Psychologically voluntary movement is a kind of movement in which sensory or ideational processes are *necessarily* functionally present. All nonvoluntary movements are therefore to be defined in biological or physiological terms; in them sensory or ideational processes are unnecessary for their efficient execution. Practiced and habitual movements, or such as are only partially racial, are, on the other hand, movements in which psychical processes are still required at critical points. Many of our instincts and practically all of our common habits belong to this grade. But whenever an instinct or a habit is for any reason lifted temporarily to the higher volitional level, it is always with an increase in clearness and definiteness of the accompanying *cognitive* processes that this is accomplished. In case of the instincts the increased clearness, together with perhaps an increased complexity, of the cognitive elements is precisely what makes the instinct a voluntary activity. Or, to state it in another way, the instinct becomes voluntary directly as the cognitive processes gain in clearness.

We should say, therefore, that instead of voluntary movement being a feeling modified by a judgment, it is rather a complex process in which a feeling reinforces the motor aspect of the focal or cognitive elements. The position here taken is that, whatever may be true in other forms of conscious states, for voluntary movement so long as feeling predominates consciousness, that is so long as the cognitive elements are submerged or "swamped"—to use Titchener's phrase—there is no *voluntary* movement; that voluntary movement can begin only with the appearance of distinct cognition or at least distinct sensation, and that with the "swamping" of the latter there goes also the disappearance of voluntary movement. It is contended that *voluntary movement means control and that control in turn means cognition.*

(4.) To this interpretation the physiological experiments of Mott and Sherrington and Munk together with the pathological cases already reviewed lend strong support. They tend to show that all movement above the reflex level requires *sensation* for its execution. They tend to show, too, that a feeling, desire to move, or *Gemüthebewegung*, without the cognitive process, is entirely incapable of controlling the movement. Certain of the cases of anæsthesia show that there are conditions when "inner" volition, or desire to make a movement, is entirely possible without the ability to make the movement, *not because it is physiologically impossible but because it is psychically impossible* for the reason that indispensable cognitive data are wanting. It follows therefore that all movement taking place while feeling is dominating consciousness is of the reflex-instinctive type; that under such conscious conditions voluntary movement is only partially, and perhaps not at all, possible; that control (the essence of voluntary movement), demands at least two things, awareness of the position of the member to be moved and consciousness of the current results of the movement.

(5.) Once more, voluntary movement necessitates voluntary or controlled attention. In fact, so close is the relation between voluntary movement and attention that if one neglects the *nature* of the processes, voluntary movement may be accounted for wholly in terms of attention. But upon what material does attention naturally operate, upon the feelings or upon the sensory and ideational processes? By what may perhaps be properly called a process of selection attention goes to those processes which by being rendered focal and clear will most facilitate control. Here, again, we have evidence for the primacy of the cognitive processes.

Voluntary movement is peculiarly psychical and therefore as a *kind* of movement almost wholly a psychological prob-

lem. Physiologically it is not a new form of movement bringing into play necessarily a new coördination. Looked at as an activity of a muscular mechanism it is highly probable that new coördinations never take rise in voluntary movement. What is new is the making of these muscular coördinations in response to psychical conditions rather than in response to purely neural and physiological conditions. In short, it is a new *control* rather than a new muscular coördination; or, to put the matter in another way, it is a new chaining together of coördinations which in themselves are old. The reflexes and the instincts supply all the neuro-muscular pathways. When these pathways are utilized under individual conditions, instead of old and racial conditions, we have voluntary movement.

It follows from what has been said that all movement as such begins as a purely physiological process; that, at least so far as the individual is concerned, the reflex or impulse is the prototype of all action. This appears so evident as to call for no detailed discussion.

A second consequence of the view here presented is that the earliest movement-consciousness is in no sense the cause of the movement, but only a by-product of a complex psychophysical mechanism, the physical aspect of which becomes operative before the mental. Experimental evidence for this is found in the studies of Bair and Woodworth, who demonstrated that there is consciousness of a single movement taking place in a larger complex movement before there is ability to control that movement in isolation. We are at times apparently conscious of our reflexes without at the same time being conscious of any control over them whatsoever. This is particularly true of instinctive behavior of the reflex type. In fact it is very probable that at any moment our conscious life is wider than its functional aspects, that in the most voluntary activities the functional processes are never coextensive and identical with the conscious processes. The functional processes never make their first appearance as such, but appear as epiphenomena and then, after they are picked out of the total conscious complex by attention, become controlling factors. In support of this point also the work of Bair affords evidence. The learning of complicated activities, in so far as they are consciously, or voluntarily, learned, like riding a bicycle, etc., illustrates the same general truth. The correct movement is reflexly made, or accidentally hit upon, under guidance of the general intention, as a consequence of excess stimulation. Certain sense elements connected with this movement are then caught by attention. These elements then become functional by virtue of the effect of attention. The

supporter of the kinæsthetic theory may contend that it is impossible to conceive how control can *begin*, except the results of the movement previously made in a reflex manner are first *imaged*. This is the position taken by James when he says: "In the chapter on the Will we shall learn that movements themselves are results of images coming before the mind, images sometimes of feelings in the moving part, sometimes of the movement's effects on eye and ear, and sometimes (if the movement be originally reflex or instinctive), of its natural stimulus or exciting cause." (Prin. of Psy., Vol. I, p. 445.) Our own position is a refinement of that set forth by James. We contend, first, that the perception or image "of its natural stimulus or exciting cause" is always sufficient to *initiate* the movement once it has been learned or practiced and that the *control* is effected by *immediate* sensations and perceptions and not by memory images of previous results. We contend further that in the period of learning or practice the process is not one in which memory images "resident or remote" play the primary rôle, but that it is on the other hand primarily a process of varied inhibition and re-enforcement, based on the perception of results, this perception being either of a kinæsthetic nature or of a visual or auditory nature, depending upon the nature of the movement and probably also upon the hereditary and acquired nature of the individual.

At this point the function of feeling in voluntary movement is apparent. The inhibition and re-enforcement are in each instance very largely due to the feeling aroused by the perception of the result. Let it be observed, however, that in each case the nature of the feeling is determined by the nature of the cognitive process.

While the purely ideational processes are of considerable importance in initiating movement and of slight importance in its control the conditions with regard to the sensory processes are reversed. Movements initiated by purely sensory processes are rarely if ever voluntary. On the other hand movements originally initiated by purely ideational processes are rarely, if ever, other than voluntary. This is only natural. Ideational processes are racially recent and novel; they are not provided with a mechanism of preformed pathways by means of which expression and control quickly become coördinated and exact. "All consciousness is motor," but not equally so, nor with equal definiteness of expression. The sensory processes are both more motor in tendency and more definite in reaction. Ideational processes, so to speak, lack a mechanism of their own. As elements in movement they have come into an organism built upon a sensory-motor basis. They have come into what Morgan has called a "going concern" and therefore as factors

in voluntary action must make use of a mechanism that is essentially sensory-motor and non-voluntary. So far then as the initiation of voluntary movement is concerned, this means a readaptation of the mechanism for ideational ends. Ideational processes are therefore necessarily present in the original initiation of voluntary movement.

So long as a purely sensory content is sufficient as a cue to adaptive movement, just so long there is a preformed sensory-motor mechanism provided for the execution of the corresponding movement. In short, there is a mechanical or "uncontrolled" response only when there is a mechanical reception of the stimulus or situation. That is, given conscious meaning in the *psychical* response, there is bound to be *control* in the *movement* response. But conscious meaning always implies the presence of ideational processes. We therefore conclude that whenever ideational processes as such are the initiatory processes there is always some control in the resulting movement. This means that ideational processes are never epiphenomenal in a movement-consciousness, provided, of course, they are related to the movement. An ideational process cannot directly initiate a movement without the movement being a controlled one, at least in its earliest stage. The presence of an ideational process means a higher level of consciousness, which in passing over into bodily activity carries with it a consciousness of the control that invariably becomes an element in the control. We cannot *think* about our movements while they are taking place without in a measure controlling them from this high-level consciousness which, whenever present, is always *functionally* present. We cannot ideationally cause a wink of the eye without to a degree at least controlling the resulting wink. We cannot think about our walking while we walk without to a degree controlling it.

This does not mean that all consciously controlled movement is *originally* initiated by an ideational process. It has already been pointed out that all sorts of processes may serve as starting points for the reason that "all consciousness is motor." It means only that when an ideational process *does* start a movement the resulting movement is, at least in its initial stages, more or less consciously controlled. But if a movement started as a non-volitional process, becomes a controlled activity, *it always becomes such in consequence of some sort of ideational process.* That is, so long as the initial sensorial process remains such (without meaning), there is no voluntary control. Control is never initiated except there be a psychical reason for it, and such "reason" cannot be found in a purely sensory process devoid of meaning. In other

words, the motive that leads to the initiation of voluntary control of a process capable of sustaining itself without such control must contain meaning, which is a psychic element of the higher level.

Nor is this meant to imply that the control as such is essentially carried on by ideational processes, however important these may be in bringing about the control. In matters of control ideational processes are only vicarious and supplementary, and even then their functional value may be questioned. Control is necessarily perceptual and sensory.

The theory of voluntary movement that has been here presented starts from a physiological process, and ends again with a physiological process, making psychic processes and attention middle terms in effecting a readjustment to the environment. This theory holds that the first control in learning a new movement is always gained by attention picking out certain elements, which in their first appearance are entirely non-functional.

It holds, too, that throughout the volitional or highest grade of movement, both clear imagery and clear perception are necessary for proper initiation and efficient control. It holds further that in the lower or practiced grade, in which attention leaves the process, it may do so by way of the substitution of a general symbol for the details of the original process to which attention was necessarily given at the beginning of the practice.

The author desires to express here his appreciation of the criticism given to this paper at every stage of its preparation by Dr. E. C. Sanford. While he is not to be held responsible for the facts cited or positions taken, his generous and stimulating criticism has been of inestimable help.